

AC and DC

Alternating Current AC always flows one way then the other - in other words, it travels continually with reversing directions. It is also continually changing between positive (+) and negative (-). The rate of changing the direction is being referred to as the frequency of the AC, which is measured in hertz Hz. Direct Current DC, in contrast, would always flow in one direction only. Its voltage is always positive or negative (either one), but may increase or decrease. An electrical signal refers to a voltage which can convey information. Amplitude refers to the maximum voltage that can be reached by a signal, and is measured in volts.

Electricity describes the flow of charge around a circuit that carries power and energy. Electricity may flow only when there is a complete circuit - there has to be a way for return trip to be made. Electrical energy in AC flows into a building's electrical circuit from the source to the ground and to earth. Without good connection to earth electricity would simply not flow. Ground and neutral are related but not the same. Neutral is the return path for electrical power to flow back to the service panel. Inside of the panel you will find the neutral wires bonded to the ground wires and also to a grounding conductor which connects that assembly to earth. Live wires are “hot” wires that carry the electrical power.

A serial circuit has only one path for current flow. A parallel circuit has multiple paths. The total flow in such a multipath circuit is equal to the sum of the currents in all its branches.

The live wire is an ungrounded conductor. The neutral wire is a grounded conductor. The Safety Ground is a grounding conductor. A ground electrode conductor originates at the neutral or equipment ground bus of the service panel. A ground electrode is in contact with the earth, which can be a building metal frame or an underground metallic pipe. A ground conductor keeps an electrical system continuous.

Basic measurement units

As of the time of this writing, the measurement system of preference for the NEC is the more “international” metric units, despite the fact that most US exam applicants are familiar (more) with the traditional inch-pound units.

Watts are the measure of power (the true power being used), while voltage is the measure of potential energy. Amps measure the amount of electricity that pass a point in a given period of time. Always remember, $\text{amps} = \text{watts} \div \text{volts}$. The power of circuit in watts is represented by P. The electromotive force in volts is represented by E. The current in amperes is represented by I. The equation is $P = E \times I$.

Ohm’s law expresses the relationship of variables known as E, I, and R. There is an equation $E = I \times R$. To be precise, the Ohm's Law states that *“...the current flowing through a conductor is directly proportional to the applied voltage, providing the temperature of the conductor remains constant”*. It somehow defines the relationships between voltage, current, and resistance. It also provides a basic formula to calculate the resistance of an element connected to a circuit. The

formula looks like this: Resistance (in ohms) = voltage (in volts) divided by current (in amps). The electromotive force in volts is E. The current in amperes is I. The resistance in ohms is R.

Resistance is all about the repulsion of electrical current within a circuit. With a voltage drop you can find difference in voltage between one end of the resistor and the other. When determining the total resistance of a parallel circuit, assuming resistors of equal value are connected then the total resistance will equal the value of the resistance of the resistor divided by the total number of connected resistors. Impedance is a combination of resistance and reactance. It is usually represented by the letter Z. NEC does not really specify any allowable amount of voltage drop on feeders and branch circuits. However, it recommends that the total voltage drop should not exceed 5% if reasonable efficiency of operation is to be expected. It further recommends that the feeders and branch circuit should not have more than 3%.

Kilo-Volt-Amperes KVA is a term that measures apparent power in units of 1000 volt-amperes. Transformers are commonly rated this way. KW kilo-watts, on the other hand, is a measure of true power units of 1000 watts.

Conductors and connections

The bottom-line is that only approved devices and conductors should be used.

"Conductors" refers to those materials that may contain movable charges of electricity. When there is an electric potential difference being impressed across separate points on a conductor, the mobile charges within the conductor will be moved such that an electric current will appear. Most conductors are metallic. Do note that all materials will demonstrate certain levels of resistance to flowing charges and will generate heat accordingly.

According to the code, those conductors that are used to carry current should be made of copper unless otherwise allowed. Copper does have resistance. In fact, as the wire length increases, the resistance within the wire will also increase. You should size conductors no less than 125% of the continuous loads plus 100% of the non-continuous loads. Conductor sizes are often expressed in American Wire Gage (AWG). In the practical world, two scales exist for measuring the sizes of wires. The Metric scale indicates the cross-sectional area of the conductor in square millimetres, while the AWG system has a system of rating numbers - the larger the number the smaller the wire and vice versa. Small wires almost always have a lower current carrying capability. Circular mil is the standard unit of a wire's cross-sectional area, typically expressed in mils squared.

No conductor should be used in such a way that the operating temperature is going to exceed that for which it is designed. The overall operating temperature can be determined by the ambient temperature, the heat generated by the current flow, the rate of heat dissipation and the temperature of the adjacent current-carrying conductors.

Ampacity is the allowable current-carrying capacity of a conductor. It is measured in amps. NEC has a table which lists the allowable ampacities of

conductors that are rated 0 –2000 volts, 60°C through 90°C, assuming an ambient temperature of 30°C. If this assumption is not true, keep in mind the higher temperature can limit the conductor's ability to safely dissipate heat. NEC does provide another table with the necessary correction factors.

When there is a need to convert from copper to aluminum conductors, a pretty common rule-of-thumb is to have aluminum that is two AWG sizes larger than copper for equivalency - you want to use one with an equivalent or higher ampacity rating while being able to maintain the same conductor temperature rating.

Connection of conductors to the terminal parts should be made securely with pressure connectors, solder lugs, or splices to flexible leads. Connection via wire-binding screws or studs and nuts that have upturned lugs or the equivalent may be accepted for 10 AWG or smaller conductors. In some cases you may want to use separately installed pressure connectors with conductors – be sure to check the ampacity and the identified temperature rating of the connectors!

Rating and insulation type

Temperature rating on the ampacity of a conductor should be selected so as to NOT exceed the lowest temperature rating of any connected termination, conductor, or device in the circuit. Conductors with temperature ratings may be used for purpose of ampacity adjustment and/or correction.